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Claims

1. Apparatus for cancellation of one or more non-stationary interfering signals for speech recognition, said apparatus including:

means for receiving an acoustic signal;

means for generating an estimated value of a magnitude spectrum of said non-stationary interfering signals; and

means for subtracting said estimated value from said received acoustic signal to produce a representation of a wanted speech magnitude spectrum.

2. Apparatus according to claim 1, wherein said means for generating estimated value includes processing means configured to estimate a transfer function for an acoustic channel between each source of said non-stationary interfering signals and said means for receiving an acoustic signal.

3. Apparatus according to claim 2, wherein said processing means is configured to estimate transfer functions for said non-stationary interfering signals produced by left and right stereo channel transmissions.

4. Apparatus according to Claim 2 or Claim 3, wherein said estimation of said transfer functions is achieved by said processing means executing an iterative algorithm on a frame-by-frame basis, the frames being constituted by said acoustic signals received during successive time periods.

5. Apparatus according to Claim 4 when dependent upon Claim 3, wherein said processing means is configured to estimate respective magnitudes of said left and right channel interference signals,

said magnitude of left channel interference signal is estimated by subtracting said right channel interference signal magnitude estimated during previous said iteration from said acoustic signal received at current said iteration; and

said magnitude of right channel interference signal is estimated by subtracting said left channel interference signal magnitude estimated during previous said iteration from said acoustic signal received at current said iteration.

6. Apparatus according to Claim 5, wherein said transfer function estimate for said right stereo acoustic channel is determined by dividing said right channel interference magnitude estimate by said interfering signal transmitted from said right acoustic stereo channel; and

said transfer function estimate for said left stereo acoustic channel is determined by dividing said left channel interference magnitude estimate by said interfering signal transmitted from said left acoustic stereo channel.

7. Apparatus according to Claim 6, wherein said right acoustic channel transfer function estimation is performed for a said iteration only if a ratio of total energy of said right acoustic stereo channel interfering signal over total energy of said left acoustic stereo channel interfering signal exceeds a predetermined threshold value; and

said left acoustic channel transfer function estimation is performed for a said iteration only if a ratio of total energy of said left acoustic stereo channel interfering

signal over total energy of said right acoustic stereo channel interfering signal exceeds a predetermined threshold value.

8. Apparatus according to Claim 7, wherein said ratio and threshold comparisons are applied to individual frequency components in spectra of said signals.

9. Apparatus according to Claim 8, wherein said left and right stereo acoustic channel transfer functions are multiplied by $(1-|\eta(k)|)$ where $\eta(k)$ is coherence of said left and right interfering signals at a frequency index k.

10. Apparatus according to Claim 4, wherein said transfer function estimate for said right stereo acoustic channel is obtained using an expression:

$$\hat{H}_{AR}(k)=\frac{Y(k)}{R''(k)}=\frac{H_{AR}(k)\,.\,R''(k)}{R''(k)}=H_{AR}(k)$$

and said transfer functions estimate for said left stereo acoustic channel is obtained using an expression:

$$\hat{H}_{AL}(k)=\frac{Y(k)}{L''(k)}=\frac{H_{AL}(k)\,.\,L''(k)}{L''(k)}=H_{AL}(k)$$

wherein $R''(k)=H_{CR}(k).C(k)$, with $C(k)$ being a common component of said left and right stereo channel signals and $H_{CR}(k)$ is a transfer function between common said left and right stereo channel transmissions, and said right stereo channel and $L''(k)=L(k)-H_{CL}(k).C(k)$, where $H_{CL}(k)$ is a transfer function between common said left and right stereo channel transmissions and said left stereo channel signal.

11. Apparatus according to any one of claims 2 to 10, wherein said processing means further comprises means for smoothing said estimated transfer functions in time domain.

12. Apparatus according to claim 11, wherein said means for smoothing in time domain comprises a first order recursive filter.

13. Apparatus according to any one of claims 2 to 12, wherein said processing means further comprises means for smoothing said estimated transfer functions in frequency domain.

14. Apparatus according to Claim 13, wherein said means for smoothing in frequency domain comprises a Finite Impulse Response filter.

15. Apparatus according to any one of claims 2 to 14, wherein said processing means includes means for performing a Fourier Transform.

16. Apparatus according to any of the preceding claims, wherein said non-stationary interfering signals are produced by an electronic acoustic device operating in a vehicle.

17. Apparatus according to any one of the preceding claims, wherein said means for receiving an acoustic signal comprises a microphone.

18. A method of cancellation of one or more non-stationary interfering signals for speech recognition, said method including steps of:

receiving an acoustic signal;

generating an estimated value for a magnitude spectrum of said non-stationary interfering signal; and

subtracting said estimated value from said received acoustic signal to produce a representation of a wanted speech magnitude spectrum.

19. Method according to Claim 18, wherein said step of generating an estimated value comprises estimating a transfer function for an acoustic channel between each source of said non-stationary interfering signals and said means for receiving an acoustic signal.

20. Method according to Claim 19, wherein said transfer functions are estimated for non-stationary interfering signals produced by left and right stereo channel transmissions.

21. Method according to any one of Claims 18 to 20, wherein said steps are executed iteratively on a frame-by-frame basis, the frames being constituted by said acoustic signals received during successive time periods.

22. Method according to Claim 21, when dependent upon Claim 20, wherein said step of estimating a transfer function includes:

estimating a magnitude of said left channel interference signal by subtracting said right channel interference signal magnitude estimated during previous said iteration from said acoustic signal received at current said iteration; and

estimating magnitude of said right channel interference signal by subtracting said left channel interference signal magnitude estimated during previous said iteration from said acoustic signal received at current said iteration.

23. Method according to Claim 22, further comprising steps of:

dividing said right channel interference magnitude estimate by said interfering signal transmitted from said right acoustic stereo channel; and

dividing said left channel interference magnitude estimated by said interfering signal transmitted from said left acoustic stereo channel.

24. Method according to Claim 23, wherein said step of estimating right acoustic channel transfer function is performed for a said iteration only if a ratio of total energy of said right acoustic stereo channel interfering signal over total energy of said left acoustic stereo channel interfering signal exceeds a predetermined threshold value; and

said step of estimating left acoustic channel transfer function estimate is performed for a said iteration only if a ratio of total energy of said left acoustic stereo channel interfering signal over total energy of said right acoustic stereo channel interfering signal exceeds a predetermined threshold value.

25. Method according to Claim 24, wherein said ratio and threshold comparisons are applied to individual frequency components in spectra of said signals.

26. Method according to Claim 25, wherein said left and right stereo acoustic channel transfer functions are multiplied by $(1-|\eta(k)|)$ where $\eta(k)$ is coherence of said left and right interfering signals at a frequency index k.

27. Method according to Claim 21, wherein said transfer function estimate for said right stereo acoustic channel is obtained using an expression:

$$\hat{H}_{AR}(k)=\frac{Y(k)}{R''(k)}=\frac{H_{AR}(k)\,.\,R''(k)}{R''(k)}=H_{AR}(k)$$

and said transfer functions estimate for said left stereo acoustic channel is obtained using an expression:

$$\hat{H}_{AL}(k)=\frac{Y(k)}{L''(k)}=\frac{H_{AL}(k)\,.\,L''(k)}{L''(k)}=H_{AL}(k)$$

wherein $R''(k)=H_{CR}(k).C(k)$, with $C(k)$ being a common component of said left and right stereo channel signals and $H_{CR}(k)$ is a transfer function between common said left and right stereo channel transmissions, and said right stereo channel and $L''(k)=L(k)-H_{CL}(k).C(k)$, where $H_{CL}(k)$ is a transfer function between common said left and right stereo channel transmissions and said left stereo channel signal.

28. Method according to any one of Claims 18 to 27, further comprising a step of smoothing said estimated transfer functions in time domain.

29. Method according to any one of Claims 18 to 28, further comprising a step of smoothing said estimated transfer functions in frequency domain.

30. A speech recognition system including apparatus according to any one of claims 1 to 17.

31. An electronic acoustic device including apparatus according to any one of claims 1 to 17.